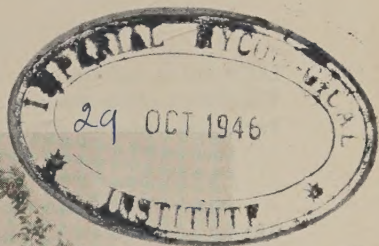


Controlling the Pre-Harvest Drop of Apples

M. B. Hoffman



THE PRE-HARVEST DROP CAUSES SERIOUS LOSSES IN MANY APPLE ORCHARDS

Published by the
Cornell University Agricultural Experiment Station
Ithaca, New York

Received for publication June 11, 1941

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CONTROLLING THE PRE-HARVEST DROP OF APPLES

M. B. HOFFMAN

The dropping of apples just prior to the development of good color and proper maturity is a problem in growing certain varieties. One of the most serious defects of the McIntosh variety in New York State is its tendency to fall from the tree before the fruits are well colored. The harvest of a good crop may start before any appreciable drop has taken place, only to have dropping increase severely from day to day. Under such conditions a moderate wind or the slight jarring of limbs incident to picking operations will result in a large loss of fancy fruit. McIntosh growers have reported the dropping of 20 to 50 per cent of the fruit before the harvest could be completed. Drop apples may be quite usable and of good eating quality, but they are always badly bruised and for this reason they must be consumed in a short period of time. The limited period during which they can be held results in a lower price than is ordinarily received for picked fruit.

In order to prevent excessive losses from the pre-harvest drop, many crops are picked before the fruit has attained maximum size, color, and quality. This is not a very satisfactory approach to the problem, because of the growing demand for apples of high color and quality. Spot picking is an alternative that results in better average color and less loss from drop, but making two or more pickings from each tree is inconvenient and increases the cost of harvesting. Another practice used by some growers is that of picking the fruit before it has started to drop, sorting out the green apples and spreading them under the trees in partial shade for color development. This involves a great deal of extra handling and the results depend considerably on the weather. Cool bright days are much more favorable for this practice than are cloudy conditions or periods of high temperatures.

Apples continue to increase in size as long as they are attached to the spur. Disregarding the thinning effect of the drop, Southwick (1940) showed that McIntosh may gain 40 per cent in volume during the month of September. If it were possible to ignore drop and depend entirely on proper maturity as a means for determining the picking date, the volume as well as the quality of the pack could be improved.

DIFFERENCE IN VARIETIES

The pre-harvest drop and its consequent interference with the development of color and quality of the fruit is more acute with some varieties than with others. The summer and fall apples, such as Williams Early Red, Early McIntosh, Wealthy, and McIntosh, are more likely to drop exces-

AUTHOR'S ACKNOWLEDGMENTS. The American Cyanamid & Chemical Corporation, through its representative, Dr. J. L. Horsfall, furnished a grant for collecting field data and supplied most of the chemicals used in these tests. Acknowledgment is made also to Morton Adams, county agricultural agent in Wayne County, and to John D. Van Geluwe, assistant county agricultural agent in Orange County, for assistance in locating orchards, spraying trees, and taking records.

sively than are late-maturing sorts such as Rome Beauty, Northern Spy, and Golden Delicious. There are many exceptions, however. For example, Yellow Transparent, a summer variety, seldom drops heavily until well past optimum picking maturity. Cortland, which usually begins to mature about the same time as does McIntosh, hangs on the tree tenaciously.

The length and flexibility of the stem and the spur may have some influence on the amount of drop. Rome Beauty and Golden Delicious have long, flexible stems which would allow some movement of the fruit without causing a strain at the point of attachment, while McIntosh has a short stem and a stiff spur so that any movement of the fruit might be conducive to drop. On the other hand, Williams Early Red, a variety with a long stem, is very susceptible to drop.

Probably of the greatest importance in the dropping of apples are the structure of the abscission layer and the chemical nature of the abscission process.

THE PROCESS OF ABSCISSION

The shedding of flowers and fruit is a natural process commonly known as *abscission*. During abscission the stem or pedicel of the flower or fruit is actually cut off from the cluster base of the spur. This may occur at petal fall, during early development of the young fruits, or later in the season, near harvest time. The nature of the abscission process for flowers and young fruits is different from that for maturing fruits.

The observations of Heinicke (1920), MacDaniels (1937, 1939), and McCown (1939) showed that early-season abscission is associated with cell division. A disk of new thin-walled cells forms across the base of the stem. The layer may be six to ten cells in thickness, and it may form anywhere in living tissue near the attachment of the stem to the cluster base. Immediately after its formation the outer layers of the cell walls dissolve away, the cells separate, and the flower or fruit drops.

Soon after the June drop, the tissues of the stems of the fruits remaining on the tree become harder owing to the formation of many thick-walled, woody fibers. This development makes the apple stem a very tough, strong structure for its size. There is a provision for the final dropping of the fruit, however, in a specialized abscission zone at the junction of the stem and the cluster base. This zone is usually marked by a constriction, which varies in depth according to the variety. The McIntosh has a deep constriction, resulting in a small cross-sectional area for support.

MacDaniels (1937) described the modifications of the normal stem as they occur in this zone. There are relatively few hard woody tissues as compared with the rest of the stem. Instead, soft living cells predominate. This condition is more pronounced in McIntosh than in Northern Spy and Delicious. Toward the outer edges of the zone, the cells are so modified that apparently it is easy for a split to start between them.

Prior to the maturing of the fruit, the abscission zone is not weak as compared with other sections of the stem. The tissues of the zone are rather tough. Thus, if immature apples are pulled, the stem will often break at some point other than the abscission zone or the spur will be torn from the branch. As maturity approaches, it becomes increasingly easy to separate the stem from the cluster base. This is not because of inher-

ent weakness of the tissue in the abscission zone, but is owing instead to changes that accompany maturity.

These changes are mostly of a chemical nature. There is no observed division of cells or formation of a new layer of cells across the abscission zone. The cell walls merely change in toughness, owing to changes in their chemical composition which cause them to split and crack. These chemical changes apparently take place more rapidly in McIntosh than in some other varieties. After formation of the abscission layer by breakdown and dissolution of the cell walls, any fibrous or woody tissue extending across the zone apparently is broken or torn from the surrounding soft tissue by mechanical strain.

FACTORS AFFECTING THE DROP

A great many studies concerning the causes of abscission of flowers and young fruits have been made. There are only a few reports, however, that give attention to the drop of maturing fruits.

SOIL FERTILITY

Shaw and Southwick (1936) reported more severe dropping of McIntosh fruits from mulched trees than from trees receiving cultivation. Their experiment was started in 1922, but no commercial fertilizer was applied to either plot until 1931 when nitrogen was applied to the cultivated trees. Several years after the mulch treatment was started, soil nitrates were found to be very high under the mulch throughout the growing season and they continued high during the fall and into the winter. Over a continuous period of sixteen years the pre-harvest drop averaged 27 per cent for the mulched trees and 16 per cent for the cultivated trees (Southwick, 1940). In spite of the higher percentage of drop, more fruit was picked from the mulched trees because of the higher yield.

Dickson (1939) showed that the length of the period of spring cultivation influenced the amount of pre-harvest drop of McIntosh. Over a four-years period, cultivating until June 15 resulted in a pre-harvest drop of 46 per cent as compared with a 24-per-cent drop for plots where cultivation was discontinued on May 15. Under the longer period of cultivation a greater total yield was produced, but, because of the high percentage of drop, the shorter period of cultivation resulted in a greater amount of picked fruit. The smaller drop associated with minimum cultivation was attributed to a reduction in the supply of soil nitrates during midseason.

In New York State an annual application of 8 pounds of sulfate of ammonia over a four-years period increased both the total yield and the pre-harvest drop of twenty-year-old McIntosh trees to the same extent. The fertilizer increased the total yield 100 bushels per acre annually, but, because of an equal increase in drop, approximately the same amount of fruit was picked from fertilized trees as from unfertilized trees (Hoffman, 1940). The check trees were unfertilized. Southwick (1940) presented data showing a positive correlation between severity of drop and increased yield induced by heavier fertilization.

CARBOHYDRATE ACCUMULATION

The light drop associated with a low nitrogen supply may be due in part

to an accumulation of carbohydrates caused by less growth of the trees. MacDaniels (1937) pointed out that fruit did not drop as readily from bearing trees which had recently been moved, as from normal trees. Because of a reduced root system, trees which have recently been moved usually make a slow growth and develop a high-carbohydrate-low-nitrogen condition. The harder tissues resulting from this type of growth may retard the process of abscission. Southwick (1940) showed that girdling of limbs in early September delayed the drop of McIntosh apples. This treatment would cause an accumulation of carbohydrates above the ring, as well as a reduced supply of nitrogen from below it.

In a fungicide test conducted by Mills,¹ the pre-harvest drop from McIntosh trees sprayed with lime-sulfur was greater than that from similar trees receiving a wettable-sulfur spray. Lime-sulfur decreases the efficiency of the foliage, and would probably increase drop through a reduction in the carbohydrate supply. In crowded orchards the drop is always observed to be heaviest in the lower half of the trees, where the foliage receives the most shade and is least efficient in the assimilation of carbohydrates.

WEATHER CONDITIONS

From observations it would seem that such factors as water supply and temperature have a pronounced effect on the dropping of apples at harvest. The effect of soil moisture may be variable, depending on the soil type and the influence of the moisture content on the nitrate supply. With equivalent nitrates available for growth, a wet season may result in more drop than a dry season because less carbohydrates accumulate when the moisture supply is excessive. The precipitation during the growing season in a Hudson Valley fruit area was 9.8 inches above normal in 1938 and 6.1 inches below normal in 1939. The pre-harvest drop of twenty McIntosh trees receiving 8 pounds of sulfate of ammonia annually was 55 per cent in the wet year and 28 per cent in the dry year (Hoffman, 1940).

The mean summer temperature is considered an important factor in determining the commercial limits of a variety. Varieties adapted to the more northern districts often drop severely when grown in a region with a high mean temperature. This is especially noticeable with McIntosh in the more southern section of its range. Even within the recognized McIntosh belt, high temperatures just prior to and during harvest appear to be associated with heavy dropping.

The pre-harvest drop in a fifteen-year-old McIntosh orchard in Orange County, New York, amounted to 25 per cent of the crop in 1939. The slightly larger crop of 1940 was harvested when the fruit was well matured and highly colored, with less than a 2-per-cent drop for all trees. Two factors probably contributed to this reduction in drop: first, the annual application of nitrogen which the trees had received for a number of years was omitted in 1940; second, the mean temperature for New York State during September 1939 was 62.0° F., or an average daily excess of 0.9 degree, while September 1940 was a cooler month with a mean temperature of 59.1°, representing an average daily deficiency of 2 degrees. Under

¹W. D. Mills, of the Department of Plant Pathology, New York State College of Agriculture. Data unpublished.

most orchard conditions a rapidly increasing drop of McIntosh is usually checked by a sudden drop in the daily mean temperature. This is shown rather clearly in figure 2 (page 15) by the curve representing the average accumulative drop for check trees.

It has been suggested that the effects of high temperature on drop may be due to an increased rate of carbohydrate respiration (Southwick, 1940). Probably a more specific and important effect of hot weather is the acceleration of those chemical changes which cause a breakdown of the cell walls of tissues in the abscission zone.

THE USE OF CHEMICALS IN DROP CONTROL

It has recently been demonstrated that certain synthetic organic chemicals are effective in preventing the pre-harvest drop of apples. These chemicals are commonly referred to as *plant growth substances* or *plant hormones*. Some of them are known to stimulate root initiation and have been used rather extensively for treating cuttings. Following the discovery that several of these materials would delay the abscission of various plant organs such as floral structures, leaves, and petioles, Gardner, Marth, and Batjer (1939) conceived the idea of spraying apple trees with them to prevent the pre-harvest drop of fruit. They found that a number of the plant growth substances would have an effect in delaying drop. Naphthalene acetic acid and naphthalene acetamide were especially effective. In later experiments with the Gallia Beauty variety, Gardner, Marth, and Batjer (1940) reported that the sodium, potassium, calcium, and ammonium salts of naphthalene acetic acid were all equally as effective as the acid itself.

Marked results with the hormone sprays were obtained by the above investigators on more than twenty apple varieties, including McIntosh. Concentrations of the chemicals as low as 0.0001 per cent (1 part per million) were effective, but higher concentrations up to 0.001 per cent gave better results. A single application of the spray delayed drop for one to three weeks, depending on the variety and on the conditions under which the spray was applied. The effect on the drop was usually noted twenty-four to forty-eight hours after spraying.

This work represents an entirely new development in the field of fruit-growing and is still considered as being somewhat in the experimental stage. However, it is now apparent that the hormone sprays will be useful in many cases. Further investigations and trials are needed to properly evaluate such factors as methods of application, timing of the spray, the most economically effective range of concentrations, differences in varietal response, dependability of the practice under various environmental conditions, the desirability of duplicate sprays, ultimate effects on fruit and tree, and any other unforeseen circumstances that may develop in connection with this method of drop control.

When the first experimental work was carried out in 1939, the chemicals were not available locally. The pure materials were procured from the manufacturer and the small amounts required for a tank of spray were weighed out in the laboratory. Since these chemicals are not readily soluble in water, they were first dissolved in alcohol and this solution was added to the water in the spray tank.

During the 1940 season, several companies manufactured and placed on the market proprietary products containing the hormones which had been found to delay drop. Because of the small amounts of the chemicals required (1.9 to 3.8 grams to 100 gallons of water) and the impracticability of weighing out such quantities under orchard conditions, the commercial preparations were made up by placing the active ingredients in suitable solvents or fillers so as to increase the bulk as well as to bring about solubility in the spray water.

A number of orchard tests were conducted in New York State during the 1940 harvest season to obtain more information on the possibilities of controlling the pre-harvest drop with hormone sprays. In all of these tests a standard procedure of record-taking was followed. All drop fruits were removed from under the trees and discarded at the time of spraying. Drop records for each tree were taken daily until the harvest was completed. At harvest time the number of bushels picked and the number of apples in 3 bushels were recorded for each tree. From these data the percentage of drop occurring from the time of spraying until harvest was calculated.

Because of the variability that may exist among individual trees with respect to dropping of fruit, trees of equal size, vigor, and amount of crop were selected for the separate treatments in each orchard. Six or more trees, depending on the number of uniform individuals available, were included in each treatment.

Commercial preparations as well as pure chemicals were used. When the concentration of the active ingredients was the same, all prepared products were found equally effective and gave just as good results as did the pure chemicals. The duplicate treatments listed in some of the tests are merely different preparations containing naphthalene acetic acid.

ON WILLIAMS EARLY RED

Some results obtained with the variety Williams Early Red are given in table 1. The apples had just begun to color and an occasional fruit

TABLE 1. EFFECT OF SPRAYS ON THE DROPPING OF WILLIAMS EARLY RED APPLES
(Trees sprayed on August 6; fruit harvested on August 16)

Treatment	Per cent drop* August 6 to August 16
0.001 per cent naphthalene acetic acid	0.3
0.001 per cent naphthalene acetic acid	0.5
0.001 per cent naphthalene acetic acid	0.3
0.001 per cent naphthalene acetamide	0.8
Check	73.8

*Average of 10 trees in each treatment, 18 years old; total yield, 10.3 bushels per tree. Temperatures on August 6: maximum 91° F., minimum 78°.

had dropped when the spray was applied on August 6. All of the treatments gave excellent control of drop for ten days. The period of effectiveness may have been longer, but extra-fancy color had developed by August 16 and it was necessary to pick the crop at this time in order to prevent overmaturity of the fruit.

The results of another test with Williams Early Red are given in table 2.

TABLE 2. EFFECT OF SPRAYS ON THE DROPPING OF WILLIAMS EARLY RED APPLES
(Trees sprayed on August 9; fruit harvested on August 16)

Treatment	Per cent drop* August 9 to August 16
0.001 per cent sodium salt of naphthalene acetic acid	1.4
0.001 per cent naphthalene acetic acid	1.2
0.001 per cent naphthalene acetic acid	0.9
Check	56.2

*Average of 8 trees in each treatment, 18 years old; total yield, 6.0 bushels per tree. Temperatures on August 9: maximum 81° F., minimum 80°.

For seven days the naphthalene-acetic-acid sprays, as well as the spray made with the sodium salt of naphthalene acetic acid, were entirely effective in controlling drop. This orchard was located only a short distance from the one reported upon in table 1, and should have been sprayed at the same time as was that orchard because there was little difference in the time of drop development in the two blocks. It is of interest to note that the daily rate of drop for the check trees in both orchards was about the same, being 7.4 per cent of the total crop dropped per day in the former and 8.0 per cent in the latter.

From observations in New York State and reports from other sections, Williams Early Red seems to respond to the effect of these chemicals as well as or better than any other variety does. Several trees in these tests did not drop a single apple from the time when they were sprayed until the fruit was harvested. This high degree of effectiveness may be accounted for in a number of ways. Williams Early Red has a long, thick, vegetative stem, and the apples hang in a vertical position so that the spray can collect in the stem cavity. Furthermore, the variety matures early in the season, when the spraying can usually be done under high-temperature conditions and when there still is a considerable growth activity in the tissues of the tree.

Williams Early Red apples usually drop heavily about the time when they begin to develop No. 1 color. Everyone familiar with the variety realizes that several spot pickings must be resorted to over a period of seven to ten days if any appreciable proportion of the crop is to be harvested with satisfactory color. With one application of the hormone spray, thoroughly applied just as the first few fruits drop, it seems possible that the entire crop can be harvested in a single picking operation after the development of fancy color. Although no concentrations of less than 0.001 per cent were used in these tests, it is likely that one-half this strength—that is, 0.0005 per cent—would prove satisfactory for Williams Early Red (Batjer and Marth, 1941). The danger of overmaturity must receive consideration when the spray is used on Williams Early Red and other varieties ripening during warm weather.

ON EARLY MCINTOSH

The fruits of Early McIntosh mature over a long period of time. The trees must be picked over at least twice, and in many cases three times, if all the crop is to be harvested at the best stage of maturity and color development. Even with this procedure there is usually a large loss from drop. The data in table 3 indicate that the harvesting of Early McIntosh

can be made more convenient, with a considerable saving of fruit, by use of the hormone spray.

TABLE 3. EFFECT OF SPRAYS ON THE DROPPING OF EARLY MCINTOSH APPLES
(Trees sprayed on August 9; fruit harvested on August 17, 21, and 26)

Treatment	Per cent drop*	
	August 9 to August 16	August 9 to August 26
0.001 per cent naphthalene acetic acid	2.2	15.6
0.001 per cent naphthalene acetic acid	1.8	11.2
0.001 per cent naphthalene acetic acid	1.3	8.8
0.001 per cent naphthalene acetic acid	0.8	5.4
Check	26.3	42.6

*Average of 7 trees in each treatment, 9 years old; total yield, 4.0 bushels per tree. Temperatures on August 9: maximum 80° F., minimum 78°.

Four naphthalene-acetic-acid preparations were used in the orchard for this test. These preparations were made for experimental use and probably will not be marketed. However, the data are presented in order to show that the effect of naphthalene acetic acid in reducing the drop of Early McIntosh extends for fully two weeks. The spraying was done on August 9. A few apples had dropped, but color had scarcely started to develop. One week after spraying, 26 per cent of the crop had dropped from the check trees, while the spray had held the drop to 2 per cent or less on all treated trees. At this time about one-third of the crop was well colored and ready for harvest. The first spot picking was made on August 17. The remainder of the crop was harvested during two later pickings on August 21 and 26. The last column of table 3 gives the percentage of the total crop that dropped from August 9 until harvest was completed on August 26, and includes in addition all apples knocked off during the three separate picking operations.

ON DUCHESS

Two rows of Duchess trees located in the center of this Early McIntosh block afforded an opportunity to conduct a small test on another variety. The Duchess trees were sprayed and picked at the same time as were the Early McIntosh. The figures on drop are given in table 4. Although the unsprayed Duchess trees did not have as heavy a drop as did the unsprayed trees of Early McIntosh, the hormone spray was very effective in reducing this drop.

TABLE 4. EFFECT OF SPRAYS ON THE DROPPING OF DUCHESS APPLES
(Trees sprayed on August 9; fruit harvested on August 17, 21, and 26)

Treatment	Per cent drop*	
	August 9 to August 16	August 9 to August 26
0.001 per cent naphthalene acetic acid	0.3	4.1
Check	5.3	21.5

*Average of 7 trees in each treatment, 9 years old; total yield, 4.5 bushels per tree. Temperatures on August 9: maximum 80° F., minimum 78°.

ON WEALTHY

A block of 120 Wealthy trees were sprayed on September 13. The trees were located on rather poorly drained land and were probably shallow-rooted. They appeared to be suffering from drouth at the time of spraying, although rainfall had been above normal for the season. The crop had been thinned and was fairly uniform throughout the orchard. A hormone concentration of 0.0005 per cent was used for the five treatments reported in table 5.

TABLE 5. EFFECT OF SPRAYS ON THE DROPPING OF WEALTHY APPLES
(Trees sprayed on September 13; fruit harvested on September 22)

Treatment	Per cent drop* September 13 to September 22
0.0005 per cent sodium salt of naphthalene acetic acid	8.4
0.0005 per cent naphthalene acetic acid	8.1
0.0005 per cent naphthalene acetic acid + 0.25 per cent summer oil	8.6
0.0005 per cent naphthalene acetic acid	7.3
0.0005 per cent naphthalene acetic acid	11.2
Check	28.2

*Average of 20 trees in each treatment, 14 years old; total yield, 5.3 bushels per tree. Temperatures on September 13: maximum 67° F., minimum 53°.

During the nine-days period prior to harvest, the sprayed trees dropped about 8 per cent of their crop as compared with 28 per cent for the checks. The apples were large, averaging 119 to the bushel, and were well colored and well matured when picked. A spray concentration of 0.001 per cent might have given better control of drop. It is possible also that the condition of the trees resulting from the unfavorable soil may have tended to reduce the efficiency of the spray.

ON MCINTOSH

It has been pointed out by Gardner, Marth, and Batjer (1940) that the control of the McIntosh drop with the hormone spray presents some special problems. A single application of naphthalene acetic acid significantly reduced the drop of McIntosh for only eight or nine days, while with most other varieties the effect of the spray persisted to a marked degree for two to three weeks. The period of effectiveness on McIntosh seemed to end rather abruptly, resulting in the immediate start of a heavy drop. Because of this short period of effectiveness on McIntosh, Gardner, Marth, and Batjer emphasized the importance of delaying the spray until positive evidence of drop was noted so as to obtain the maximum protection at the time when the drop is heaviest. If an extension of this period of drop control is desired, it was suggested that a duplicate application made four or five days following the first application might be tried.

In the McIntosh tests reported here, special attention was given to the timing of the sprays. The orchards were selected for the test a week or more in advance of the spraying. At this time all drop apples were cleaned up from under a dozen or more trees in various parts of the orchard. These apples were usually fruits which had dropped prematurely because of insect injury, poor pollination, or some other condition. The trees were then inspected daily for the drop of good, commercial fruit.

When 2 to 6 sound apples per tree were found to have fallen over a period of twenty-four hours, it was assumed that abscission was starting, and the spray was applied. It is felt that this method of timing the spray on McIntosh is fairly reliable. Unless the weather is unseasonably warm, there are usually several days of a light and scattered drop before the heavy drop starts.

A 5-acre block of vigorous thirteen-year-old trees was used for a comparison of the treatments listed in table 6. This orchard had been sprayed

TABLE 6. EFFECT OF SPRAYS ON THE DROPPING OF MCINTOSH APPLES
(Trees sprayed on September 16; fruit harvested on September 24 and 25)

Treatment	Per cent drop* September 16 to September 24-25
0.0005 per cent naphthalene acetic acid	3.1
0.001 per cent naphthalene acetic acid	2.9
0.001 per cent naphthalene acetic acid + 0.25 per cent vegetable oil	2.8
0.0005 per cent naphthalene acetic acid, duplicated September 21	2.7
Check	20.2

*Average of 25 trees in each treatment, 13 years old; total yield, 6.4 bushels per tree. Temperatures: on September 16, maximum 73° F., minimum 64°; on September 21, maximum 82°, minimum 62°.

with mild fungicides and well fertilized. The pruning had been heavy, which permitted very thorough spraying. The large, efficient foliage may have accounted for the moderate drop of the check trees, which were located systematically throughout the block. About one-half of the trees in each treatment were picked on September 24 and the remainder on September 25. All of the spray treatments appear to have been equally effective in controlling the drop for eight to nine days. During harvest there was no evidence of an acceleration in the rate of drop from any of the treated trees, while the amount of fruit lost by the checks was increasing daily. It would seem that this crop of fruit would have benefited by remaining on the trees for several more days. If the grower had delayed the harvest for the development of better color and maturity, the stronger concentrations and the duplicate applications might have shown to advantage.

The effect of a duplicate application of naphthalene acetic acid on heavily dropping McIntosh trees is shown in table 7. The trees were twenty-five years old. They had been heavily fertilized with manure and were greatly in need of pruning. The fillers had not been removed, resulting in a crowded condition with the ends of the lower branches overlapping as much as 2 feet between trees. The maximum drop is usually expected under such orchard conditions.

TABLE 7. EFFECT OF SPRAYS ON THE DROPPING OF MCINTOSH APPLES
(Trees sprayed on September 17 and 23; fruit harvested on September 28)

Treatment	Per cent drop* September 17 to September 28
0.001 per cent naphthalene acetic acid (duplicated)	3.6
Check	48.0

*Average of 6 trees in each treatment, 25 years old; total yield, 17.5 bushels per tree. Temperatures: on September 17, maximum 73° F., minimum 59°; on September 23, maximum 76°, minimum 59°.

The pre-harvest drop was just starting when the first spray was applied, on September 17. Not more than 24 commercial apples had fallen from any tree. The second spray was applied on September 23. Both applications were made when the temperature was above 70° F. The drop was controlled for eleven days. It is possible that this duplicate application would have controlled the drop somewhat longer, but the fruit was picked on September 28 to prevent overmaturity.

The accumulative percentage drop for the check and the sprayed trees is shown graphically in figure 1. Apparently the first spray was timed cor-

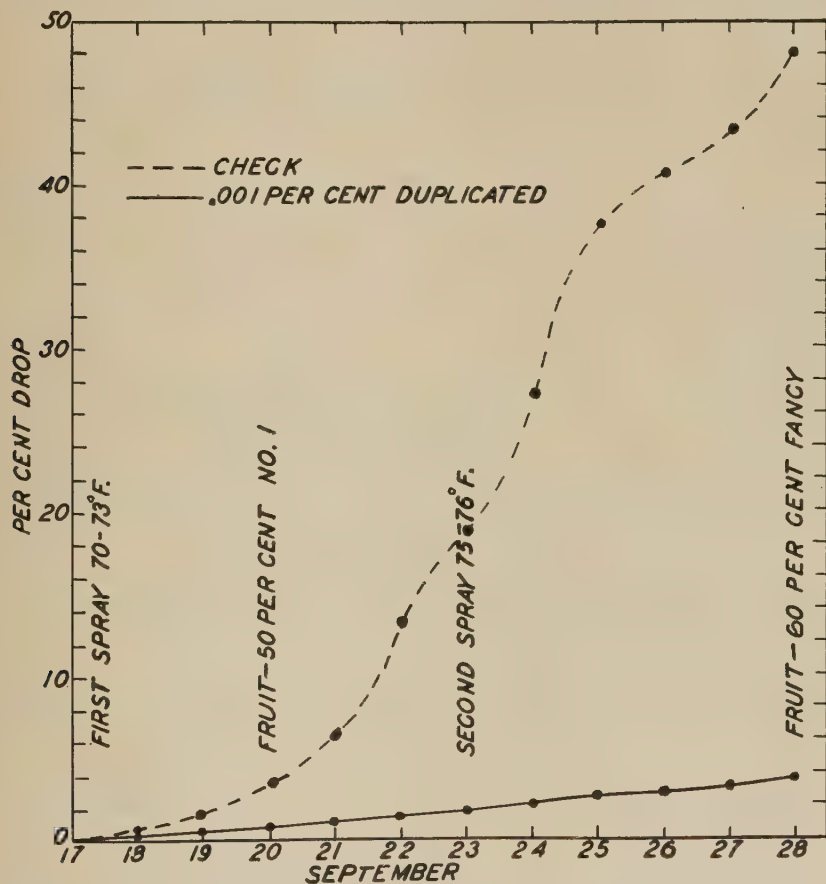


FIGURE 1. AVERAGE ACCUMULATIVE PERCENTAGE DROP OF UNSPRAYED (CHECK) TREES AND OF TREES RECEIVING DUPLICATE APPLICATIONS OF HORMONE. FIRST SPRAY CORRECTLY TIMED

rectly in this orchard, as is indicated by a distinct separation of the drop curves twenty-four hours after spraying. At the end of the eleven-days period there is still no evidence of a sharp increase in the drop of the sprayed trees. With heavily dropping trees and under the conditions of this test,

the duplicate application has resulted in a longer period of drop control than did the single application reported upon by Gardner, Marth, and Batjer (1940).

Duplicate and single applications of three hormone preparations were made in a vigorous eighteen-year-old McIntosh orchard. The trees had received good care, were well pruned, and were bearing a uniform crop. Because of the growers' past experience with the drop problem in this orchard, most of the trees receiving the single application were picked seven days after spraying; consequently the records do not help in the evaluating of any additional benefit that might have come from the second application. The data are given in table 8.

TABLE 8. EFFECT OF SPRAYS ON THE DROPPING OF MCINTOSH APPLES
(Trees sprayed on September 18 and 26; fruit harvested on September 25 and 30)

Treatment	Per cent drop*	
	September 25	September 30
0.001 per cent sodium salt of naphthalene acetic acid	0.7	...
0.001 per cent naphthalene acetic acid	1.6	...
0.001 per cent sodium salt of naphthalene acetic acid	2.0	...
Check	13.4	38.3
0.001 per cent sodium salt of naphthalene acetic acid	2.0	5.8
0.001 per cent naphthalene acetic acid	2.1	5.1
0.001 per cent sodium salt of naphthalene acetic acid	2.1	5.1

*Average of 11 trees in each treatment, 18 years old; total yield, 19.5 bushels per tree. Temperatures: on September 18, maximum 76° F., minimum 59°; on September 26, maximum 57°, minimum 45°.

The first spray, applied on September 18, was resulting in a good control of drop on September 25 when harvest of the first three treatments was completed. At that time only 60 per cent of the fruit had developed U. S. No. 1 color. The No. 1 fruit was packed, and the commercial grade was returned to the orchard and spread under trees for color development. A second application of the spray was made with the three remaining treatments on September 26. These trees were harvested with the checks on September 30, at which time good picking maturity had developed and 80 per cent of the crop had fancy color.

The accumulative percentage drop for the check trees and one of the duplicated treatments is plotted in figure 2. The curves indicate that the first application was applied about two days too early. The checks did not begin to drop appreciable quantities of fruit until September 22. The slight increase in the rate of drop of the sprayed trees from September 28 to 30 indicates that the effect of the hormone was running out. No benefit in the control of drop can be ascribed to the second spray, applied on September 26. The temperature ranged between 55° and 57° F. when this application was being made. The drop curve for the check trees shows that this period of cool weather reduced the rate of the normal drop for about two days. It is possible that the cool weather caused an apparent extension of the period of effectiveness of the first application, and at the same time resulted in an initial lag of any effect that may have come from the second spray. This interpretation would agree with the observations of Gardner, Marth, and Batjer (1940).

Another test was conducted in a fifteen-year-old McIntosh orchard, com-

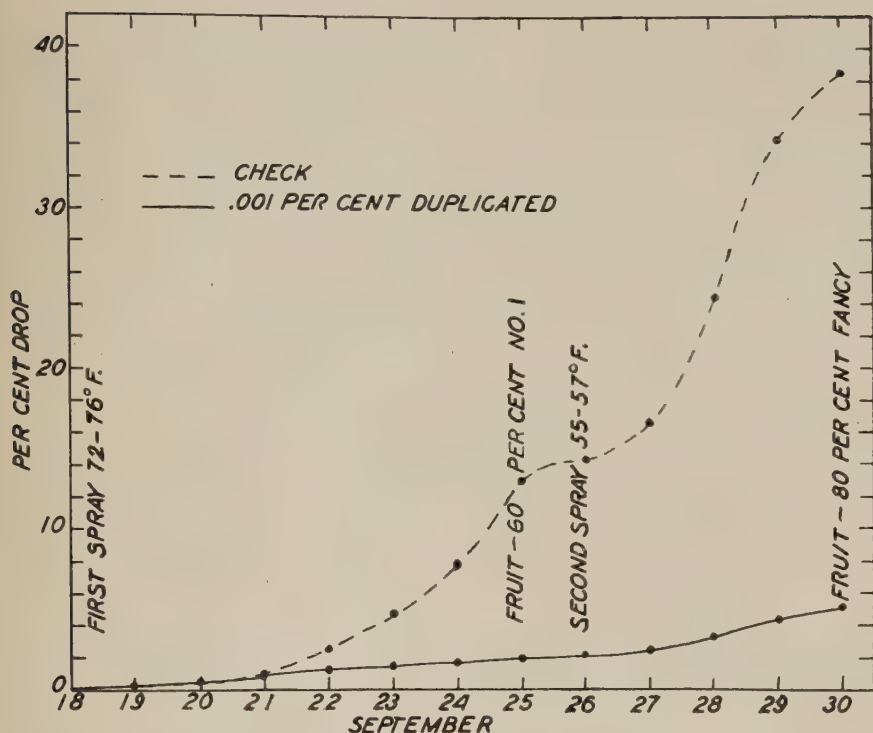


FIGURE 2. AVERAGE ACCUMULATIVE PERCENTAGE DROP OF UNSPRAYED (CHECK) TREES AND OF TREES RECEIVING DUPLICATE APPLICATIONS OF HORMONE. FIRST SPRAY APPLIED TWO DAYS TOO EARLY

paring several hormone preparations at concentrations of 5 parts per million, and three different oils in combination with the hormone at 10 parts per million. The trees were very vigorous, having been liberally fertilized with chicken manure. This entire block was hand-pollinated during bloom, since there were no other varieties in or near the orchard for cross-pollination. The apples were well spaced and developed good size, averaging 112 to the bushel. The results are given in table 9.

TABLE 9. EFFECT OF SPRAYS ON THE DROPPING OF MCINTOSH APPLES
(Trees sprayed on September 20; fruit harvested on September 26)

Treatment	Per cent drop* September 20 to September 26
0.0005 per cent naphthalene acetic acid	8.4
0.0005 per cent naphthalene acetic acid	8.0
0.0005 per cent sodium salt of naphthalene acetic acid	7.8
Check	24.3
0.001 per cent naphthalene acetic acid + 0.25 per cent oil	4.7
0.001 per cent naphthalene acetic acid + 0.25 per cent oil	3.9
0.001 per cent naphthalene acetic acid + 0.25 per cent oil	4.2

*Average of 10 trees in each treatment, 15 years old; total yield, 12.0 bushels per tree. Temperatures on September 20: maximum 86° F., minimum 69°.

There was no difference in the effect of the separate preparations at the weaker concentrations. The stronger concentrations, when used with the different oils, gave about equal results. As would be expected, the stronger concentrations with oil seemed to give somewhat better control of drop than did the weaker concentrations without oil. One of the oils was a vegetable oil; the other two were mineral oils of light viscosity, designated as "40" and "62". These oils left no greasy residue on the fruit, and it is possible that they could be used at higher concentrations if the use of oil should ever prove desirable.

The accumulative percentage drop for the check trees and for one treatment at each concentration is shown in figure 3. As the curves indicate,

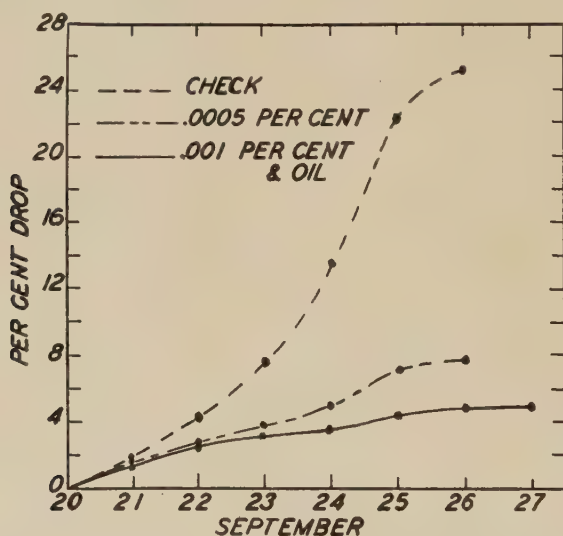


FIGURE 3. AVERAGE ACCUMULATIVE PERCENTAGE DROP OF UNSPRAYED (CHECK) TREES AND OF TREES RECEIVING SINGLE APPLICATIONS OF 0.0005 PER CENT AND 0.001 PER CENT HORMONE. SPRAY APPLIED ABOUT TWO DAYS LATE

all the trees were dropping fruit at the time when they were sprayed. The spray should have been applied about two days earlier; however, it is of interest to note that the hormone checked the drop after the drop was well under way.

DISCUSSION

The dropping of apples just prior to and during the regular harvest period is a fault of many varieties and is recognized as a serious problem in the production of McIntosh. Certain practices, such as spot picking and after-harvest coloring, have been used in an attempt to reduce the loss from drop. While these practices will often improve the situation, they increase the cost of harvesting and handling.

The abscission process, which results in the dropping of fruit, is characterized by a chemical dissolution of the cell walls in the abscission zone. The time and the severity of the drop seem to be associated with such factors as soil fertility, soil moisture, carbohydrate supply, and weather con-

ditions. Such practices as heavy nitrogen fertilization, heavy mulching, and late cultivation tend to increase the pre-harvest drop. Fertilization of trees with nitrogenous materials is necessary for good yields, but it can be overdone. When the drop is excessive, omitting the fertilizer for a year or reducing the amount applied should be considered. Any system of culture that would reduce soil nitrates and excessive moisture during late summer would result in less drop and better color of the fruit.

The drop problem always appears worse under conditions of a low carbohydrate supply. An efficient leaf surface is necessary in order to meet normal carbohydrate requirements. This is best obtained by a well-distributed pruning and the use of mild fungicides. There is some evidence that wet seasons and high temperatures during harvest are the principal weather conditions that increase drop.

The use of hormone sprays to prevent drop has met with more success than was anticipated. These chemicals have proved to be very effective in controlling the pre-harvest drop of such summer varieties as Williams Early Red, Early McIntosh, and Duchess. While the period of effective drop control may not be quite so long with McIntosh as with some other varieties, it seems that the materials could be used profitably on McIntosh because of the commercial value of the variety and its susceptibility to drop.

Correct timing of the spray on McIntosh is very important if satisfactory results are to be obtained. The spray should be applied about the time when the drop of good commercial fruit starts. This will vary from orchard to orchard, but it is not hard to determine if the trees are watched carefully. By clearing the ground of all drop apples under several vigorous trees in different parts of the orchard a week or more in advance of harvest, a daily inspection of these trees will show the first drop of commercial fruit and will help in timing the spray.

Thorough spraying is essential. Gardner (1940) found that the best results followed when the spray was applied to the region of the abscission zone. Large trees should be sprayed from the underside as well as from the outside, and enough pressure should be used to force the material in around the cluster base and the stems of the fruit. The control of drop will be no more effective than the coverage given. In the test reported upon here, about 1 to 1¼ gallons of spray was used to each bushel of fruit. The material was applied at 450 to 500 pounds pressure.

There is no definite evidence, in any of the McIntosh tests, that a duplicate application has prolonged the period of drop control. Batjer and Marth (1941) reported little additional benefit from a second application on this variety. They concluded that one spray properly timed would control drop for ten to twelve days, and they doubted that a second spray would extend this period unless the initial spray had been applied too far in advance of drop. If one application properly timed will control drop for ten to twelve days, then most crops of McIntosh would need to be harvested by that time in order to prevent overmaturity of the fruit.

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